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Transformational Changes on Public Transport in China through Electric Vehicle and e-Mobility

(Background Paper for EST Plenary Session-3)

Final Draft

This background paper has been prepared by Tianshu Zhang, Madan B. Regmi and Ganesh Raj Joshi for the 13th Regional EST Forum in Asia. The views expressed herein are those of the authors only and do not necessarily reflect the views of the United Nations.

Transformational Changes on Public Transport in China through Electric Vehicle and e-Mobility[1]

Tianshu Zhang[1], Madan B. Regmi[1] and Ganesh Raj Joshi[2]
[1]United Nations Economic and Social Commission for Asia & the Pacific
[2]United Nations Centre for Regional Development

I. Introduction

Electric-mobility solution are getting popularity worldwide to address the existing transport externalities, particularly air pollution and Green House Gas emissions (GHGs). The Chinese Government has committed to bring transformational changes in their public transport system through electric mobility solution. On 22 September 2020, President Xi Jinping announced that P. R. China (hereafter China) aims to have CO2 emissions peak before 2030 and achieve carbon neutrality before 2060at the 75th session of the General Assembly of the United Nations. As an initiative, the Government already introduced several policy measures in support of and accelerate to the e-mobility in major cities. In 2009, China launched the Electric Vehicle Promotion Scheme to develop and support the industry of electric vehicles (EV) both national and local level. The government also adopted electrification of vehicles with highest priority in the 12th Five-Year National Plan (2011-2015). Eventually, the electric vehicle industry was selected as one of the seven strategies emerging industries by the National Development and Reform Commission (NDRC) of the Government of China.

Since 2009, Central Government and Local Governments are supporting to electric vehicle industry through three major policy reform (i) more funding for research and development of innovative electric vehicles technologies, (ii) proving assistance to manufacture industry for electric vehicles and related equipment development, and (iii) supporting for public and private consumption of the electric vehicles. Starting from 13 major cities including Shanghai, Shenzhen, Changchun, Hangzhou, Hefei, etc., now the scheme has covered in most of the provinces in China. Since then, electric public transport has increased rapidly. For instance, by2019, there have been about 670,000 urban buses in Chinese cities, among which about 340,000 are new energy buses, accounting for 51%, ranking first in the world (reference-…). The annual passenger traffic volume of urban public transport is more than 90 billion. Both the number of electric buses and passenger traffic volume in China rank first in the world (Xinhua News Agency, 2019).

II. National Policy Reform

There are number of actors for developing national policies related to electric vehicle and e-mobility in China. The Ministry of Industry and Information (MIIT) which is responsible for industrial policy, planning and related standards development

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for the electric vehicle and related industries. The Ministry of Science and Technology (MOST) is looking after national research and development programs related to the electric vehicles associated development. The Energy Bureau is responsible for heading the development of infrastructure particularly electric vehicle charging facilities. And the National Standardization Administration of China (SAC) is the key organization for development, approval, and promotion of the national standards for electric vehicles and charging facilities.

The Chinese Government has implemented numerous effective national policies in support of the development and improve the electric vehicles and to promote the e-mobility in China - automobile industry plan, fuel-efficient and new energy development plan, and investment in new energy vehicles, among other. These policies incorporate multiple areas: (i) macroscopic directive, (ii) governmental subsidy scheme, (iii) industrial management, (iv) safety supervision, (v) charging infrastructure, (vi) technical standard, among other (Li, 2018).

During these policy reform, the electric charging infrastructures are especially strengthened. The technical standards, industrial management, safety supervision and vehicle performance mechanism are increasingly improved. The technical requirements are more and more strict to stimulate a healthy market competition. As a result, the popularity rate of the electrification of the public transport system in China has increased significantly in recent years. The penetration rate of the electric public transport buses (ratio of electric buses to the total amount of buses) in major cities in China has increased rapidly (Fig.1). The data reveled that main areas to promote electric public transport are mainly Beijing-Tianjin-Hebei (key area of 'Blue sky defense' Action Plan), Yangtze River Delta Region (Shanghai, Hangzhou, Nanjing, etc.), Pearl River Delta Region (Shenzhen, Guangzhou, etc.).

The major national policies initiatives that the Government of China has introduced to promote the electrification of the public transport system are listed below

Table 1. National policies related to electrification of the public transport system in China.

Year	Policy	Main content
2009	Notice on the pilot work of demonstration and promotion of new energy vehicles (NEV [1])	Determined 13 pilot cities to promote new energy vehicles, defined financial support especially in public service, e.g. PR, taxies, sanitation, post, etc., formulated subsidy schemes for vehicle purchasing of Non-NEV.
2013	Notice on continuing the promotion and application of new energy vehicles	Continued promoting NEV in more cities, formulated subsidy schemes for consumers, provided financial rewards for outstanding demonstration cities in charging infrastructure development.
2015	Implementation strategies on accelerating the promotion and application of new energy vehicles in the transport sector	Set the goal of 300,000 NEVs (200,000 urban electric buses), improved some details of implementation, e.g. the

		standards of vehicles and charging infrastructure, etc.
2015	Notice on improving the price subsidy policy of oil products for urban buses and accelerating the promotion and application of new energy vehicles	Decreased the current oil price subsidy policy for urban buses, identified the price subsidy policy for NEVs, especially in the regions that have achieved the promotion goals.
2016	Notice on adjusting the financial subsidy policy for the promotion and application of new energy vehicles	Updated subsidy policy for NEVs, identified reward-and-punishment system.
2018	Eight key missions of the Ministry of Transport to tackle environment pollution	Set the new goal of 600,000 NEVs (400,000 urban electric buses) in 2020.
2019	Notice on supporting the promotion and application of new energy buses	Substituted subsidies with rewards to encourage the development of urban electric buses, managed to fix up the 'short board' of charging infrastructure.

Note: New energy vehicles (*NEV) incorporates battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV) and fuel cell electric vehicles (FCEV).*

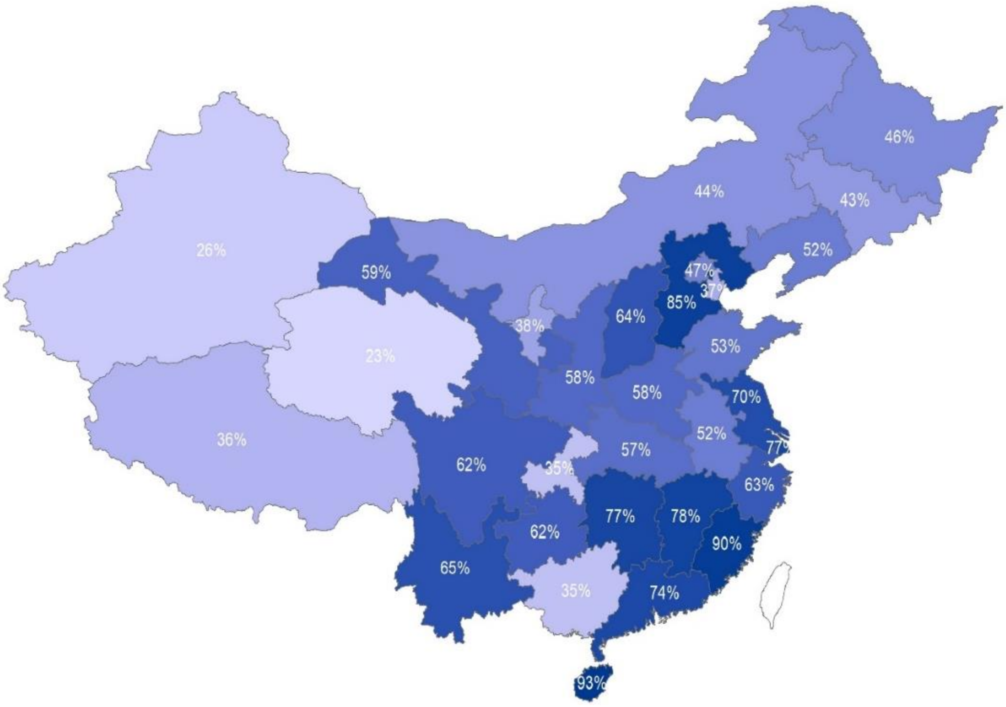


Figure1. Penetration rate of electric public transport in different provinces (2018)
Source: 2019 China's Auto Market Almanac

III. Policy Support

The supportive policies that directly impact the development of electric public transport mainly formulating the promotion plan, providing subsidies for purchasing and operational support, etc.

Promotion plan

As for promotion plan, each province or city has distinct aimed quantity of vehicles in certain time ranges. The policies related to promotion plans in certain representative provinces/cities/regions are summarized as follows (Li et al., 2017).

Table 2. Promotion plans set by local polices

Province/City/Region	Policy
Beijing-Tianjin-Hebei	In 2020, the ratio of NEVs in the newly added or updated urban buses should be more than 35% in Beijing-Tianjin-Hebei Region.
Shanghai	The proportion of new energy buses newly added or updated shall not be less than 60%.
Shenzhen	The proportion of new energy buses newly added or updated shall not be less than 70%.
Hainan Province	The proportion of new energy buses newly added or updated shall not be less than 80%.
Jiangsu Province	In 2016, the proportion of new energy buses newly added or updated shall not be less than 50%.
Zhejiang Province	During the 13th Five-year Plan[1], the utilization rate of NEVs in public transport should be more than 30%.
Shandong Province	During the 13th Five-year Plan, the utilization rate of NEVs in passenger buses, urban public transport and taxis should be more than 30%, 70% and 100%.
Shanxi Province	In 2016, the proportion of new energy buses newly added or updated shall not be less than 50%.
Shaanxi Province	The quantity of NEVs should be more than 7000, more than 50% of the quantity of urban buses in the province. The newly purchased NEVs in public service should be more than 30%.

Note: Five-Year Plans are a series of social and economic development initiatives issued in China. The time range of 13th Five-year Plan is 2016-2020.

The 13th Five-year plan guidelines concerning urban public transport have formulated that for cities at prefecture level or above, the proportion of NEVs in public transport shall not be less than 35%.

Subsidy policy

There are two major subsidy policies introduced by the Government of China - state level subsidies by the central government and local subsidies by local governments. The funds of state subsidies are issued through the operation of local governments, and the implementation details are also handed over to the local governments. However, the corresponding local policies mainly involve the subsidy fund management, with little further explanation about the application of state subsidies. Therefore, the state subsidy policy is still essential to conduct analysis (Hu, 2020).

- In terms of purchasing subsidies, the support for different types of NEVs have been shrinking in the recent years. Table 3 is the estimation of the subsidies for different vehicle types. The actual subsidies vary according to the specific technical standards (energy consumption per unit load of vehicle, continuous driving range, etc.)

Table 3. Purchasing subsidies for NEVs in public transport
(Unit: thousand CNY/ vehicle)

	2016	**2017-2018** (20% decreased based on 2016)	**2019-2020** (40% decreased based on 2016)
Slow charging	500	400	300
Fast charging	380	304	228
Plug-in hybrid	200	160	120

Source: China Public Transportation Association

- In case of operation subsidies, great differences have shown between NEVs and traditional diesel-powered buses. The operation subsidies for NEVs have been supportive through the years, while the subsidies for diesel-powered buses keep decreasing. The total amount of oil subsidies has been reduced to less than one third of the original amount.

Table 4. Operation subsidies for NEVs in public transport
(Unit: thousand CNY/ vehicle)

	2016	**2017**	**2018**	**2019**	**2020**
Slow charging	80	80	80	80	80
Fast charging	80	80	80	80	80
Plug-in hybrid	40	40	40	40	40
Traditional hybrid	20	20	20	20	20
Diesel-powered	5.6	4.8	4	3.2	2.4

Source: China Public Transportation Association

According to Hu (2020), the total costs for different types of buses in 8 years are: Fast-charging < Slow-charging < Plug-in hybrid < Traditional hybrid < Diesel-powered. The fast-charging electric vehicles are typically the most benefit-effective type of NEV. Although slow-charging electric vehicles are given the highest amounts of subsidies, the production cost is also higher, which makes it less competitive. It is obvious that diesel-powered buses show little advantage at all compared to NEVs. The subsidy policy demonstrates an obvious attitude to encourage and develop the use of NEVs in public transport. It also fits the strategy of 'substitute subsidies with rewards' in the policy '*Notice on supporting the promotion and application of new energy buses*' issued in 2019.

IV. Electric Vehicle and Charging System

Since 2011, the sale of electric buses increased 101 times in 2016. Due to the policy change in 2016, conservative actions were taken, and the sales were decreased to a certain extent, which is clearly shown in below graph (Fig.3)The data was collected until the first half of 2019.

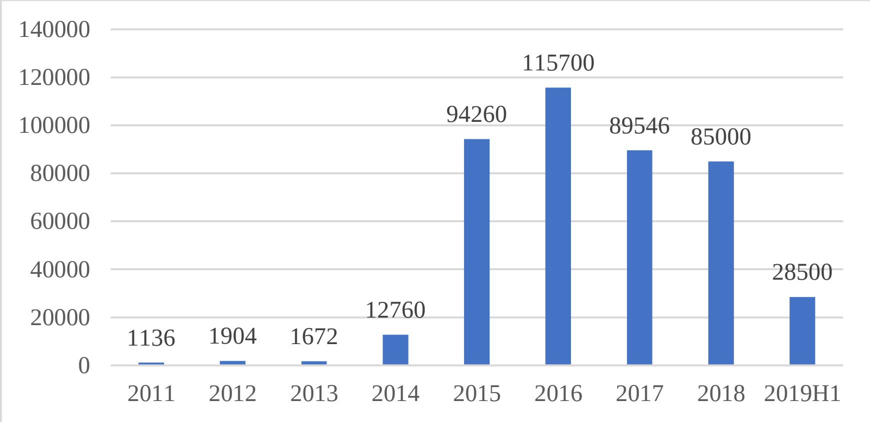


Figure 3. Electric bus sales in China between 2011 and 2019.
Source: Qianzhan Institute of Economics

After the upgrading of technology over these years, 'fast-charging' and 'slow-charging' are two main charging methods that are adopted in China. Besides, there are also charging methods including battery swapping, on-line charging (trolleybus), wireless charging, etc. However, due to the immaturity, pitfalls and expense of these technologies, these methods are not popular in the market.

Table 5. Main battery system of NEVs

Battery system	Popularity	Technical maturity	Cost
Slow-charging	High	Relatively high	High cost in battery
Fast-charging	Relatively high	Relatively high	High cost in charging infrastructure
Battery swapping	Low	Medium	High cost in charging station construction
On-line charging	Low	High	High cost in auxiliary infrastructure
Wireless charging	No	Low	High

In case of the vehicle size, 10-12 meters vehicles are pre-dominant, taking up to 61% in the total fleet. However, the share of it is still little and needs to be increased. One of the reasons why the sizes of the vehicles are increasing is the inclination of the newly updated supportive policies towards larger-size buses. Another reason is the technical improvement of batteries.

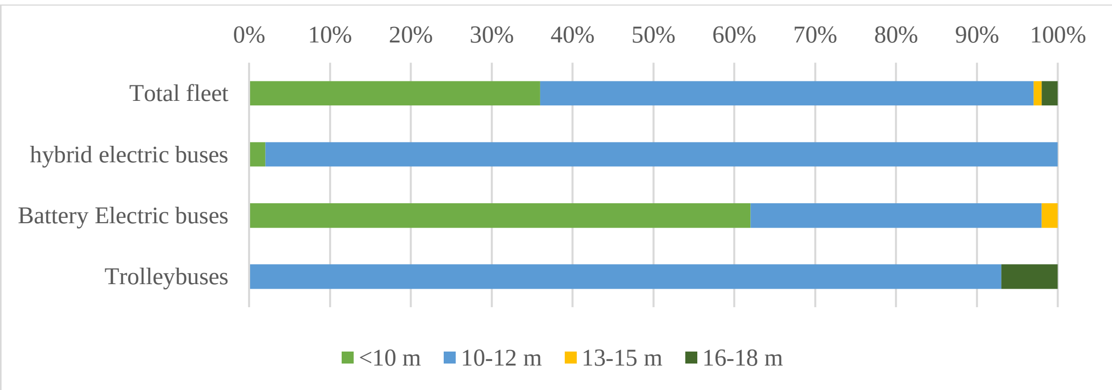


Figure 4. Vehicle size of the bus fleet

Source: Asian Development Bank

The energy density (average value) of the supporting battery system of battery electric passenger vehicles rose from 100.1 Wh/kg in the 1st batch in 2017 to 150.7 Wh/kg in the 7th Batch in 2019, increasing 50.5% over the year.

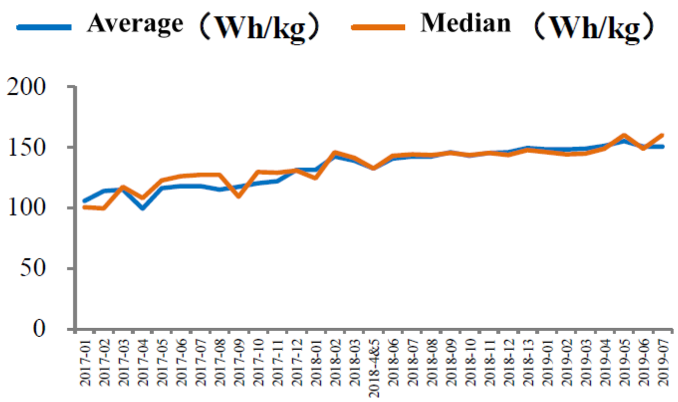


Figure 5. Statistics of battery density (2017-2019)

Source: Evergrande Research Institute

Almost 100 automobile manufacturers in China have the capabilities of NEV production. Except Yutong, all the other manufacturers only have the share of less than 20%, which indicates a competitive and diversified market.

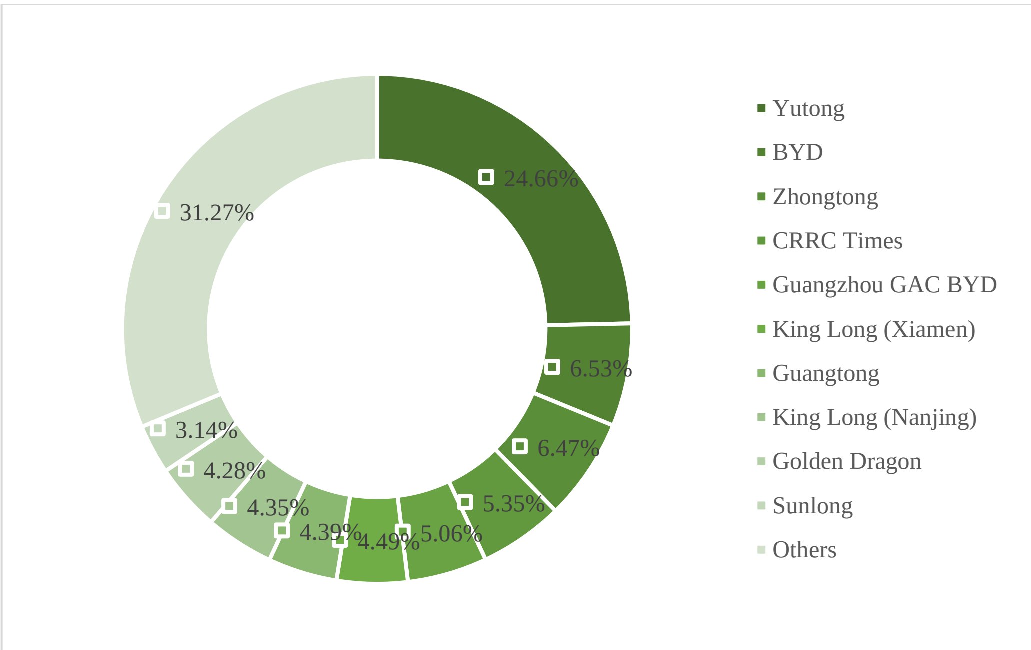


Figure 6. Market share of automobile manufacturers

Source: 2019 China's Auto Market Almanac

Charging infrastructures

Charging stations and infrastructures are rapidly developing in all over China in recent years. As of 2019, the total of 976000 charging infrastructures have been built in China with the growth rate of 71% per year. Among them, 401000 were public charging piles, and the growth rate of these charging piles has accelerated significantly since 2019, with a year-on-year growth rate of 51%. In March 2020, new infrastructure project was announced which expected to further accelerate to build vehicle charging infrastructure facilities all over China

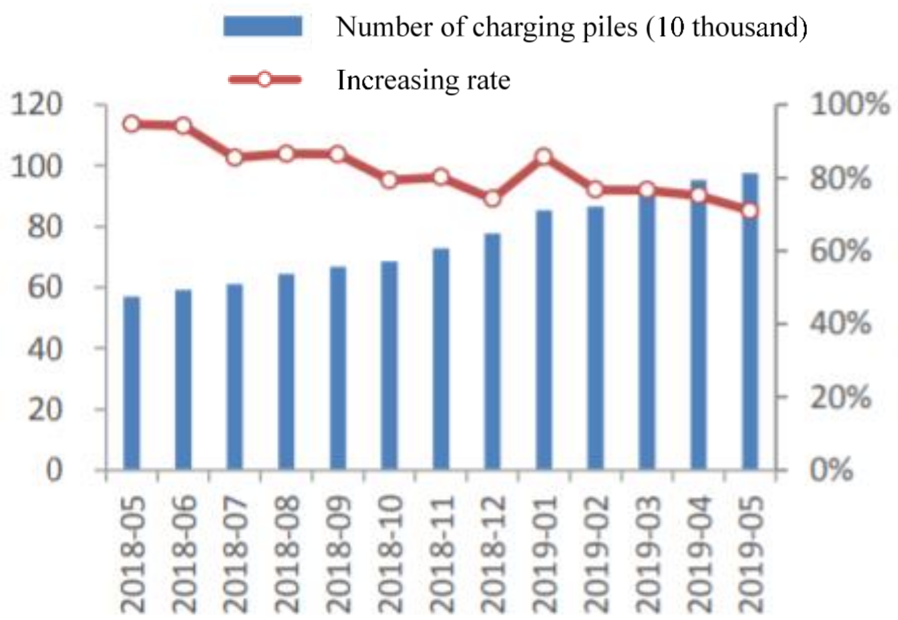


Figure 7. Quantity of charging infrastructure

Source: Chin

The challenges of the hardware industry are the relatively low threshold and the growth is mainly driven by volume. The industry has very weak bargaining power and lower gross profit rate. The enterprises without large-scale production or core technology has been gradually filtered out (Huang, 2020).

Operation

Increase the operational efficiency of electric vehicle particularly public transport system is genuine concern. Li (2019) proposed the evaluation framework of the operation of urban electric public transport system, (Fig.8).

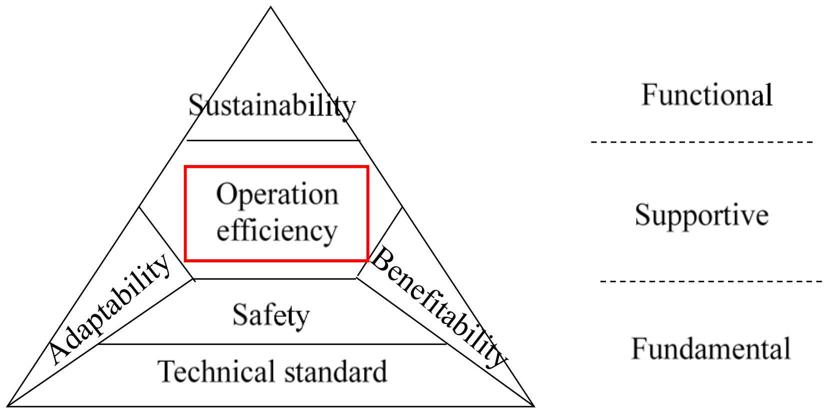


Figure 8. Evaluation framework of the operation of urban electric public transport

As for the operation efficiency, adapting the new vehicles and infrastructure into daily use is another problem faced by the operators of public transport. According to Xue et al (2019), there are several indicators to evaluate the operation of public transport system

- On-line rate of vehicles: the ratio of buses in operation to the total buses;
- Average daily driving range per vehicle;
- Number of vehicles per route: taking the ratio as 1:1 for fuel buses, if one fuel bus is substituted by two electric buses, the ratio is 2:1 for electric buses

Table 6. Operation indicators of fuel buses and electric buses

Indicators	Fuel bus	Electric bus
On-line rate of vehicles	90%	66%
Average daily driving range per vehicle	203	123
Number of vehicles per route	1:1	2:1 or 3:2

Source: World Resource Institute

It is important to maintain a satisfying operation indicator to motivate further implementation and improvement. The differences in the indicators are resulted from multiple reasons in practice, both the characteristics of the vehicles and the operation methods. The strategies to arrange the operation and coordinate the vehicles will be explained further in further-coming sessions

V. Vehicle

There are several important technical standards of NEVs in public transport which includscharging method, vehicle size, battery performance, etc., by which the electric buses can be classified into different categories. Proper selection of the vehicle type is essential for economic performance and successful operation.

Charging method

How the vehicles are charged directly influences how they are operated. As mentioned in Section II, most of the electric vehicles in Chinese cities adopt either slow-charging or fast-charging method. There is no specific boundary between 'slow' and 'fast'. Usually, if the charging rate is more than 1.6 C, it is identified as 'fast-charging' by vehicle or battery manufacturers and vice versa. (Xue et al., 2019).

Fast-charging NEVs maintain long driving ranges as much as possible with multiple times of charging and fast charging rate. On the contrary, slow-charging system has slower charging rate and efficiency, which requires the times of charging as few as possible during the days. The different decisions between the two charging methods are resulted from their different characteristics and different background of the cities. According to Xue et al (2019), the cities that select slow-charging NEVs are more sensitive to the driving ranges, while those that select fast-charging NEVs focus more on both driving ranges and charging rate.

Table 7. Comparison of two charging methods

	Slow charging	**Fast charging**
Popularity	More adopted	Less adopted
Technical standard	High	To be improved
Battery capacity	High	Low
Charging rate	Longer (c.a. 1-2 hours)	Shorter (ca. 0.5 hour)
Driving range	120-240 km	50-120 km
Times of charging per day	0-1	2-4
Price	Higher price of vehicles.	Higher price of charging infrastructure
Typical cities	Shenzhen, Shanghai, Suzhou, Wuhan, Zhengzhou, Hangzhou, Qingdao, etc.	Beijing, Guiyang, Chengdu, Chongqing, etc.

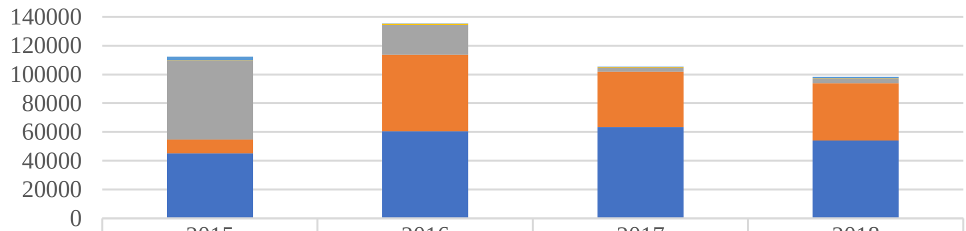
Source: World Resource Institute

The selection of slow-charging or fast-charging does not always remain the same, which could vary according to the technological standards. However, the corresponding charging infrastructure, maintenance professionals, vehicle components are also important factors to consider when updating the new system.

Vehicle size

In terms of the vehicle size of the electric buses, although about 56% of the traditional fuel gas buses in Chinese cities are large vehicles with a length of more than 10 meters (Asian Development Bank, 2018). However, due to the limitations of battery capacity, driving range, purchase cost, nearly 50% of the newly added or updated electric buses are shorter than 10 meters in length in the early stage of promotion. Recently, this trend is being reversed. The proportion of NEVs longer than 10 meters is increasing year by year, from 30% of annual sales in 2015 to 54% in 2018. More and more NEVs of 10-12-meter length on trunk lines are also gradually electrified. However, for better performance the technology of 18-24-meter NEVs still needs to be improved.

As the trend shows, the NEV buses of 8-10 meters long in China have been increased while the smaller size of 6-8 meters long is gradually filtered out. This is directly resulted from the change of subsidy standards for the different vehicle sizes.



	2015	2016	2017	2018
<6m	2484	22	66	721
>12m	140	819	350	391
6-8m	54836	20820	2943	3243
8-10m	9539	53081	38381	39904
10-12m	45297	60531	63474	53983

10-12m 8-10m 6-8m >12m <6m

Figure 9. Distribution of vehicle sizes

Source: 2019 China's Auto Market Almanac

Battery performance

Battery is the core component of NEVs, which has gained much support. The increasing vehicle size also somehow reflects the improved battery performance. Shi (2017) summarized the technical development of battery for NEVs as follows:

- The **battery capacity** is growing higher and higher. Although the high power increases the driving range of the vehicles, the absolute weight of the single battery also increases.
- The **capacity of single cell** is getting larger and larger. The soft package battery has improved from about 10A·h to about 60A·h now, and the square battery from 80A · h to 300A · h. The increase of monomer capacity leads to higher electric current, which will undoubtedly increase the heating capacity of the battery system and the wire weight, which is not helpful to save energy.

- The energy density of battery increased continuously. However, **the vehicle energy density increased slowly**. At present, the technology to improve battery energy density is relatively unadvanced. The energy density can be improved by increasing the cell size to reduce the shared quality of cell packaging or increasing the compaction to reduce the amount of electrolyte. But these two methods are likely to increase the internal resistance of the battery system, which increases the heat released. The large size of the battery is also detrimental to dissipate the heat inside the battery. Forced air cooling or water cooling is therefore needed.

- There are many kinds of single battery capacity, which makes it **difficult to reutilize the batteries after decommissioning**. In order to increase the energy density, almost every battery factory updates the cells for several times each year. Because the cells produced by different manufacturers in the same year and produced by the same battery factory in different years cannot be mixed to use after decommissioning, which increases the overall cost of the battery.

The driving range and charging speed of pure electric buses fluctuate with the seasons and years, which leads to the enterprises to adjust the traffic scheduling plan regularly, and even to eliminate the vehicles with fast battery attenuation in advance. However, it also faces the bacteria of technical problems including air conditioning, seasonal fluctuation, driving conditions, etc. According to the Institute of science and technology of the Ministry of transport (2019), the major issues concerning the aging of battery are the battery capacity and temperature.

- **The aging of battery is more severe when the capacity is higher**. For vehicles with higher battery capacity, it is difficult to maintain the consistency of battery and the aging is fast, which makes the slow-charging NEVs with large battery capacity may be more severe.

- **The aging of battery is more severe when the temperature is lower**. The aging of battery is faster in extremely cold regions such as northeast part of China.

It has been identified that the future development of the battery system mainly focuses the following points (Shi, 2017):

- In the short term, **the energy density of the battery system is still unable to achieve the goals** of longer driving range and less energy consumption at the same time. The hybrid electric bus which can give full play to the advantages of high-efficiency electric mobility and energy braking recovery is an ideal choice. The battery system of the hybrid electric buses needs to be low-electricity, low-capacity, high-voltage, high-power, high energy efficiency of charge and discharge.

- From the perspective of battery, **fast-charging electric bus is one of the most important future trends**. The battery system for fast-charging buses is low-power, long-life, fast-charging and high-efficiency. The purpose of low-electricity of fast-charging battery is to reduce the vehicle weight as much as possible, which further achieve the goal of energy saving and cost benefit. However, fast charging usually occurs in the daytime, which is not helpful to avoid the peak power consumption.

- **The current material system should be innovated to further develop the battery system with high energy density**. Slow-charging battery system is designed with high electricity to meet the requirements of a whole day. Taking the high-safety lithium iron phosphate battery as an example, the energy density is 160W·H/kg, and the weight of the battery system is 1.25t. It is difficult to reduce the total mass of the battery without significant improvement of the material system, which is not helpful to reduce the weight of the whole vehicle.

Other technical standards

In October 2016, China Automotive Engineering Society issued the 'The Technology Roadmap of Energy-saving and New Energy Vehicles', which put forward the requirements on the performance indicators of NEVs in public transport, such as power consumption, driving ranges, acceleration time, maximum speed, etc. The requirements are set in a chronological order for different coming phases.

Table 8. Requirements on the performance indictors

Vehicle type	Indicators	2020	2025	2030
Electric buses	Power consumption	<3.5 kW·h /100 km·t	<3.2 kW·h /100 km·t	<3.0 kW·h /100 km·t
Fuel cell buses (12 meters)	Driving range	500 km	600 km	>600 km
	acceleration time (0-50 km/h)	20 s	18 s	16 s
	Fuel consumption	<7 kg/100km	<6.5 kg/100km	<6 kg/100km
	Maximum speed	80km/h	80km/h	80km/h
	Life-cycle range	400,000 km	800,000 km	1000,000 km
	Cost	<1.5 million CNY	<1.0 million CNY	<0.6 million CNY

Source: China Automotive Engineering Society

V. Charging infrastructure

Now, most of the charging infrastructure is developed for public transport (Cheng & Long, 2019). For example, in Shanghai, most of the charging infrastructure is used in public transport. Due to its characteristics such as specified routes, regular charging time and large power consumption, it is advantageous to scale up. The charging stations can be set in the initial and terminal stations, bus yards, central stations, etc.

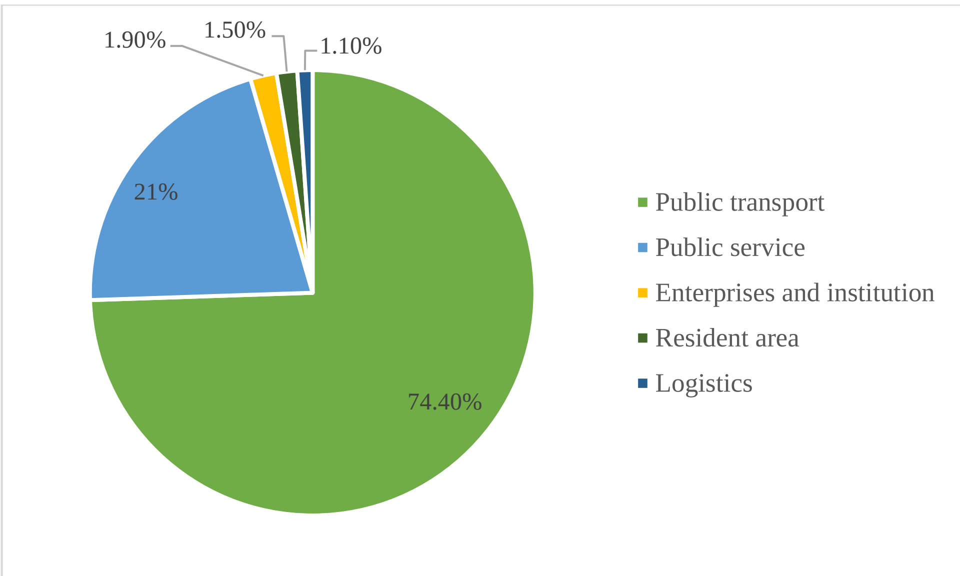


Figure 10. The usage of charging facilities in Shanghai
Source: China Merchant Bank Institute

As for the operation of charging facilities, there are mainly four patterns (Wang, 2018):

- *BT (build-transfer):* After passing the general contracting, financing and construction acceptance, the project enterprises hand over the construction of charging facilities to the public transport enterprises. The public transport enterprises will pay the project investment and return to the investors. Example: Guangzhou, Xiamen.

- *BOOT (build-own-operate-transfer):* The charging facility enterprises provide professional services. The public transport enterprises authorize the charging facility enterprises to finance, design, build, operate and maintain the infrastructure. The charging facility enterprises charge the professional service from the public transport enterprises. Example: Shenzhen.

- *Self-build and self-use:* Public transport enterprises purchase charging facilities through public bidding and raise the funds for construction. They take the responsibility for the process of planning, design, procurement, implementation, operation and management. The property and management rights belong to the public transport enterprises. Example: Foshan, Zhaoqing.

- *PPP (public & private partnership):* Under the guidance of the government, the government (or the public transport enterprises) collaborate with the bid-winning private enterprise to establish a company for charging facilities construction and operation through government procurement. The established company is responsible for financing, design, planning, construction and operation to provide charging services for public transport enterprises. Charging facilities construction and operation company established by property right and operation right. Example: Shaoguan, Nanchang.

According to “Guidelines for the development of electric vehicle charging infrastructure (2015-2020)” (National Development and Reform Commission Energy -2015, No.1454), the goal is to complete 3850 new charging stations for electric public transport (Li, 2018). Until now, for both centralized charging stations and distributed charging stations, majority of them are privately owned (40%). There are some stations for changing batteries instead of charging the vehicles, but very few in amount.

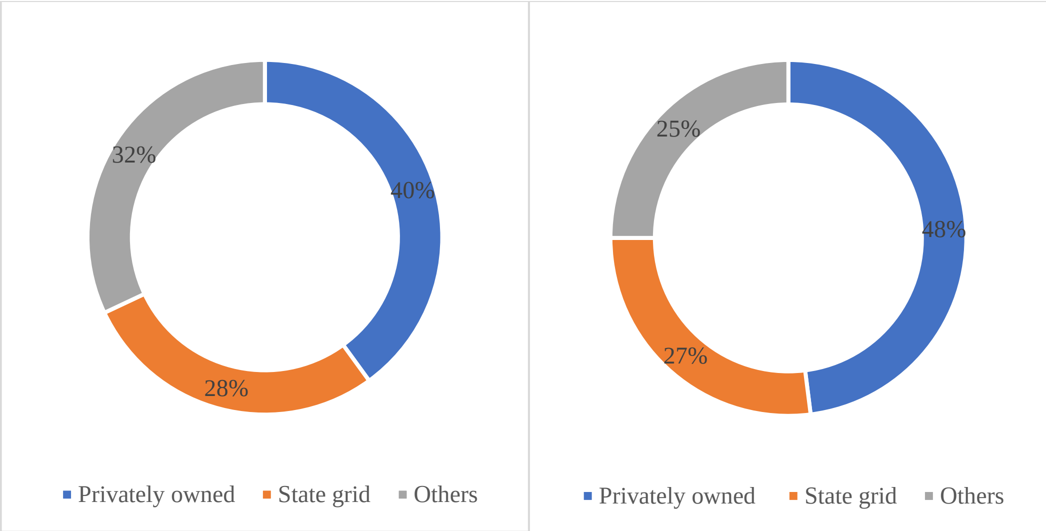


Figure 11 1. Ownership share of the charging stations
(Left: centralized charging stations; Right: decentralized charging piles)
Source: Shenzhen Urban Transport Planning and Design Institute

In '*Notice on incentive policies for charging infrastructure of new energy vehicles during the 13th five-year plan and strengthening the promotion and application of new energy vehicles*', the subsidy standard was set to support the construction for charging infrastructure.

Table 9. Subsidy standard for NEV charging infrastructure

	Region	**Basic subsidy**	**Maximum subsidy**	**Number of cities/ provinces**	**Cities/ provinces**
1	Key areas of air pollution and important regions	0.53 billion CNY	0.8 billion CNY	10	Beijing, Shanghai, Tianjin; Guangdong, Zhejiang, Jiangsu, Shandong province
2	Middle provinces and Fujian province	0.35 billion CNY	0.8 billion CNY	6	Anhui, Jiangxi, Henan, Hubei, Hunan, Fujian province
3	Others	0.2 billion CNY	0.8 billion CNY	15	Other provinces/ cities except above

As two complementary industries, the current charging infrastructure and new energy vehicle industry have gradually balanced the development. After years of exploration, the operation mode and profit model of charging infrastructure have been basically mature. The industry is about to bloom with promising prospects. On the basis of the current subsidy policy on charging infrastructure, the new policy of NEV industry also clearly points to the link with charging infrastructure, which is believed to promote a new batch of enterprises or projects in the manufacturing and operation of charging infrastructure (Huang, 2020).

VI. Operation

The major factors that deserve attention when transiting to electrification are the differences in driving ranges and charging characteristics:

- Usually, the **driving range of electric buses for one time of full charging is shorter** than that of traditional fuel buses. Proper routes should be planned to fit the driving ranges (battery capacity) of electric buses.

- The operation time for traditional fuel buses is mainly made up of driving time and vacant time at the terminals. However, **extra time should be arranged for queueing and charging** for electric buses. If the charging station is not at the terminals, return time when the buses are 'empty-cruising' should be also taken into account.

Xue et al (2019) put forward several strategies during the transition to electrification according to the conditions of the different cities:

Table 10. Strategies during the transition to electrification and corresponding conditions

Strategies	Advantages	Conditions
1) Only peak shifts are substituted by electric buses while the others (all-day shifts) remain unchanged.	No new buses need to be added; No new schedule has to be made.	Early stage of the transition.
2) All buses are substituted by electric buses. All-day shifts are replaced by one morning shift and one evening shift.	Easier to make the schedule.	Early stage of the transition. Inadequate charging facilities. Undesirable battery function.
3) All buses are substituted by electric buses. Shorten the working time of all-day shifts and add more buses (about 15%).	Easier to make the schedule.	Early stage of the transition. Inadequate charging facilities. Undesirable battery function.
4) All buses are substituted by electric buses. Prepare some spare buses (about 9%) for use when the buses of all-day shifts are charging.	Fewer extra buses are added.	Mature stage of the transition.
5) All buses are substituted by electric buses. Charge the buses of all-day shifts during interval of service.	No new buses need to be added.	Mature stage of the transition. Desirable battery function. More complicated schedule arrangement.

We should be aware that the traditional methods to manage and dispatch the buses will not be suitable. Instead, it is an opportunity to develop a more accurate and intelligent system to adapt to the new technological transition.

For example, based on the technologies of NEVs, big data and intelligent network connection, Suzhou is aiming to improve the technology monitoring, coordination management and travel service technology of new energy buses. The main tasks of the platform are:

- Open up data interface, establish an integrated information interaction platform of ‘passenger-vehicle-route-station-pile-network’.
- Coordinate the buses and thus improve passengers’ travel efficiency and experience, guide the traffic flow and route planning.
- Supervise and ameliorate traffic safety.
- Optimize the accuracy and flexibility of urban public transport service.

It relates to the National Monitoring Center, with rich experiences and mature technologies in commercial NEV operation (Higer bus, 2019).

VII. Conclusion and recommendation

The transition from traditional fuel buses to electric buses is a complicated process concerning many factors including policy support, vehicle, charging infrastructure and operation. It recalls the active involvement of multiple stakeholders including central and local governments, vehicle and battery manufacturer, charging infrastructure developer, public transport operator, etc.

Reviewing the four factors discussed above, the development trends of electric public transport are summarized as below:

- **Policy support:** The policies on electric public transport have been supportive since 2009. The subsidies are being gradually withdrawn in the recent years, turning from fast growth to steady growth, from an immature pattern to a well-developed pattern. Promotion plans are made by local governments step by step.

  The policy makers should be aware that the transition to electric transport system will not be an immediate process and the measures should be adapted gradually to its specific context in terms of society, economics and environment. Measurements include subsidy schemes (production, research & development, purchase, etc.), financial support, technological formalization, reward-and-punishment system, emission tax on conventional fuel, portfolio standards, and different combinations of above. The series of policies initiatives should be continuously implemented and dynamically adjusted according to the result evaluation, economic research and information disclosure.

- **Vehicle:** Slow-charging and fast-charging are two most commonly adopted charging methods of current electric buses. The battery function is becoming improved, for which the larger-size electric buses are put more into use. However, there are still some bottlenecks to overcome to optimize the vehicle performance of energy-saving and emission reduction.

The standards of NEVs should be strictly defined, combined with the characteristics of public transport in technical requirements, service requirements, vehicle configuration, etc. (Gong, 2017) A good collaboration of vehicle manufacturers and public transport operators in all the aspects would be necessary to foster the technological development of vehicles in a longer life cycle and a more practical scope.

- **Charging infrastructure:** The current charging infrastructure and new energy vehicle industry have gradually balanced the development. The construction of the charging infrastructure is also highly encouraged by the subsidy scheme.

  A well-developed system of charging infrastructure is critical to the success of the electrification of the transport system. The construction of the charging infrastructure should be synchronized with the urban spatial planning, land use planning and the capability of energy supply. As for public transport, it is more advantageous to develop the charging infrastructure once the scale is formed. The charging time schedule, route arrangement, facility standard, site selection are the significant points that are worth investigation and optimization.

- **Operation:** Several operation strategies are proposed according to the experiences of some Chinese cities. However, different adjustments should be made based on the actual background conditions. Except the operational aspects concerning schedule, routes, drivers, etc., innovative management tools and platforms incorporating novel data analysis methods and intelligent technology can be further developed.

  Based on the traditional operation patterns, novel and innovative strategies should be adopted for the smooth process of electrification. Empirical conclusion is necessary at the first step, however, a better coordination with policy support, vehicle technology, charging infrastructure should be developed. The potential bottlenecks should be identified from the beginning of the transition and solved, for instance, whether the battery capacity is suitable for the route ranges, whether bus schedule is flexible for future possible increase in the travel demands, etc. In addition, employees in the public transport operation sectors should receive systematic training and education to adapt to the new mode.

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